PROPOSED
TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

South Fork Obion River (HUC 08010203) Watershed

Carroll, Gibson, Henderson, Henry, Obion, and Weakley Counties, Tennessee

DRAFT

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TDEC

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LIST OF ABBREVIATIONS

AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DA	Drainage Area
DEM	Digital Elevation Model
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Plan
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
UCF	Unit Conversion Factor
UTK	University of Tennessee, Knoxville
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. Coli in Selected Waterbodies of the South Fork Obion River Watershed (HUC 08010203)

Impaired Waterbody Information

State: Tennessee
County: Carroll
Watershed: South Fork Obion River (HUC 08010203)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document (from the Final 2006 303(d) List):

Waterbody ID	Waterbody	RM not Fully Supporting
TN08010203001 – 0700	CLEAR CREEK	3.6

Designated Uses:

The designated use classifications for the impaired waterbody in the South Fork Obion River watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Water Quality Goal:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January, 2004* for recreation use classification (most stringent):

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 ml, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 ml shall be considered as having a concentration of 1 per 100 ml.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall not exceed 487 colony forming units per 100 ml. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 ml.

TMDL Scope:

Waterbodies identified on the Final 2006 303(d) List as impaired due to E. coli. The TMDL was developed for the impaired waterbody on a waterbody drainage area basis.

Analysis/Methodology:

The TMDL for the impaired waterbody in the South Fork Obion River watershed was developed using a load duration curve methodology to assure compliance with the E. coli 126 CFU/100 mL geometric mean and the 941 CFU/100 mL maximum water quality criteria. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow regime represented by these existing loads. A load duration curve was used to determine the load reduction required to meet the target maximum concentration for E. coli. When sufficient data are available, load reductions are also determined based on the geometric mean criterion.

Critical Conditions:

Water quality data collected over a period of up to 10 years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

Seasonal Variation:

The 10-year period used for LSPC model simulation and for load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Explicit MOS = 10% of the E. coli water quality criteria for each impaired subwatershed or drainage area.

TMDLs, WLAs, & LAs

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

HUC-12 Subwatershed (08010203__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs[a,b]			LAs[e]
				WWTFs[c]		Leaking Collection Systems[d]	
				Monthly Avg.	Daily Max.		
			[% Red.]	[CFU/day]	[CFU /day]	[CFU /day]	[% Red.]
0102	Clear Creek	TN08010203001 – 0700	82.3	9.541×10^{9}	7.125×10^{10}	0	84.1

a. There are no CAFOs in the impaired subwatershed of the South Fork Obion River watershed. All future CAFOs will be assigned waste load allocations (WLAs) of zero.

b. There are no MS4s in the impaired subwatershed of the South Fork Obion River watershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.

c. WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet in-stream water quality standards at the point of discharge as specified in their NPDES permits.

d. The objective for leaking collection systems is a WLA of zero. It is recognized, however, that a WLA of 0 CFU/day may not be practical. For these sources, the WLA is interpreted to mean a reduction in E. coli loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

e. The load allocations (LAs) listed apply to precipitation induced nonpoint sources only. The objective for all other nonpoint sources (leaking septic systems, illicit discharges, and animals access to streams) is a LA of zero. It is recognized, however, that for leaking septic systems a LA of 0 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in E. coli loading to the maximum extent feasible, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL) SOUTH FORK OBION RIVER WATERSHED (HUC 08010203)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those waterbodies that are not attaining water quality standards. State water quality standards consist of designated uses for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the South Fork Obion River Watershed identified on the Final 2006 303(d) List as not supporting designated uses due to Escherichia coli (E. coli). The South Fork Obion River watershed lies entirely in the state of Tennessee. TMDL analysis was performed on a waterbody drainage area basis.

3.0 WATERSHED DESCRIPTION

The South Fork Obion River watershed (HUC 08010203) is located in northwestern Tennessee (Figure 1) and lies within the Level III Southeastern Plains (65) and Mississippi Valley Loess Plains (74) ecoregions as shown in Figure 2 (USEPA, 1997). The impaired subwatershed lies in the Level IV Southeastern Plains and Hills (65e) ecoregion:

- The Southeastern Plains and Hills (65e) contain several north-south trending bands of sand and clay formations. With elevations reaching over 650 feet, and more rolling topography and more relief than the Loess Plains to the west, streams have increased gradient, generally sandy substrates, and distinctive faunal characteristics for West Tennessee.

The South Fork Obion River watershed, located in Carroll, Gibson, Henderson, Henry, Obion, and Weakley Counties, Tennessee, has a drainage area of approximately 1159 square miles (mi^2). Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the South Fork Obion River watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the South Fork Obion River watershed is summarized in Table 1 and shown in Figure 3. Predominate land use in the South Fork Obion River watershed is agriculture (61.0%) followed by forest (36.3%). Urban areas represent approximately 2.0% of the total drainage area of the watershed. Details of land use distribution of the E. coli-impaired subwatershed in the South Fork Obion River watershed are presented in Appendix A.

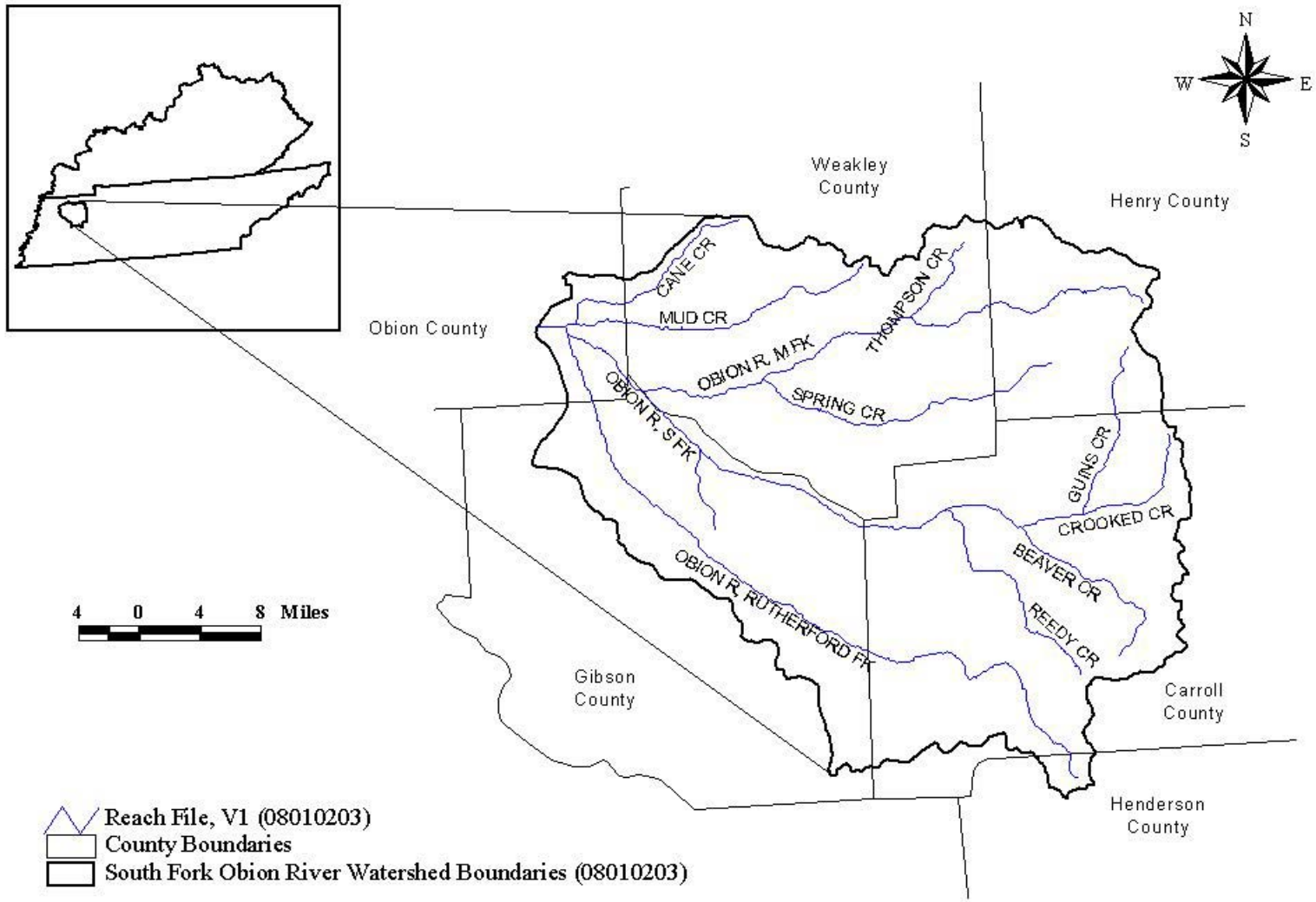

Figure 1. Location of the South Fork Obion River Watershed.

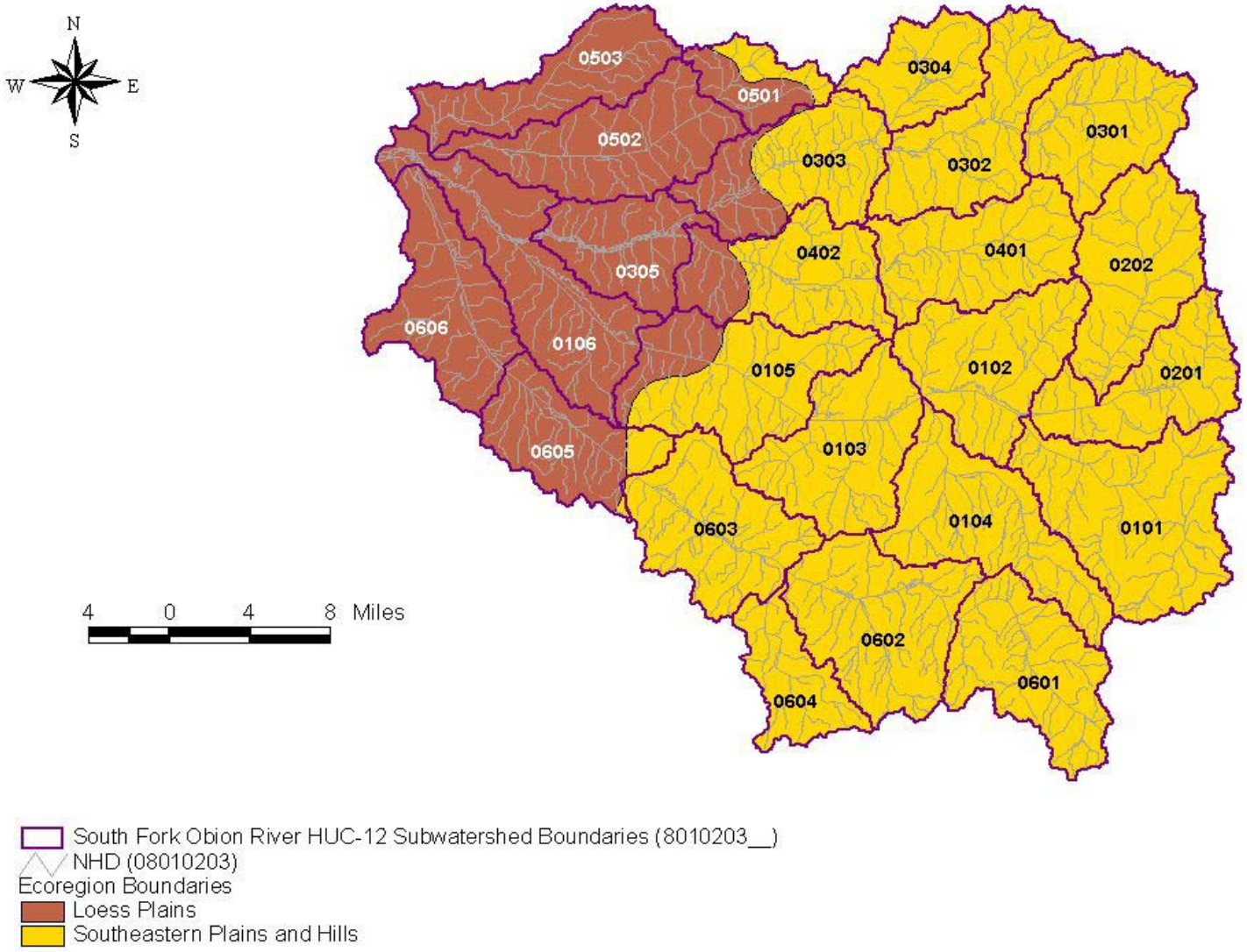

Figure 2. Level IV Ecoregions in the South Fork Obion River Watershed.

4.0 PROBLEM DEFINITION

The State of Tennessee's Final 2006 303(d) List (TDEC, 2006) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in October of 2006. The list identified one (1) waterbody segment in the South Fork Obion River watershed as not fully supporting designated use classifications due, in part, to E. coli. See Table 2 and Figure 4. The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Table 1. MRLC Land Use Distribution – South Fork Obion River Watershed

Land Use	Area	
	[acres]	[%]
Deciduous Forest	164,337	22.2
Evergreen Forest	18,586	2.5
High Intensity Commercial/ Industrial/Transportation	3,160	0.4
High Intensity Residential	1,093	0.1
Low Intensity Residential	9,037	1.2
Mixed Forest	42,482	5.7
Open Water	4,355	0.6
Other Grasses (Urban/recreational)	461	0.1
Pasture/Hay	256,699	34.6
Quarries/Strip Mines/Gravel Pits	450	0.1
Row Crops	195,794	26.4
Transitional	1,314	0.2
Woody Wetlands	43,837	5.9
Total	**741,604**	**100.00**

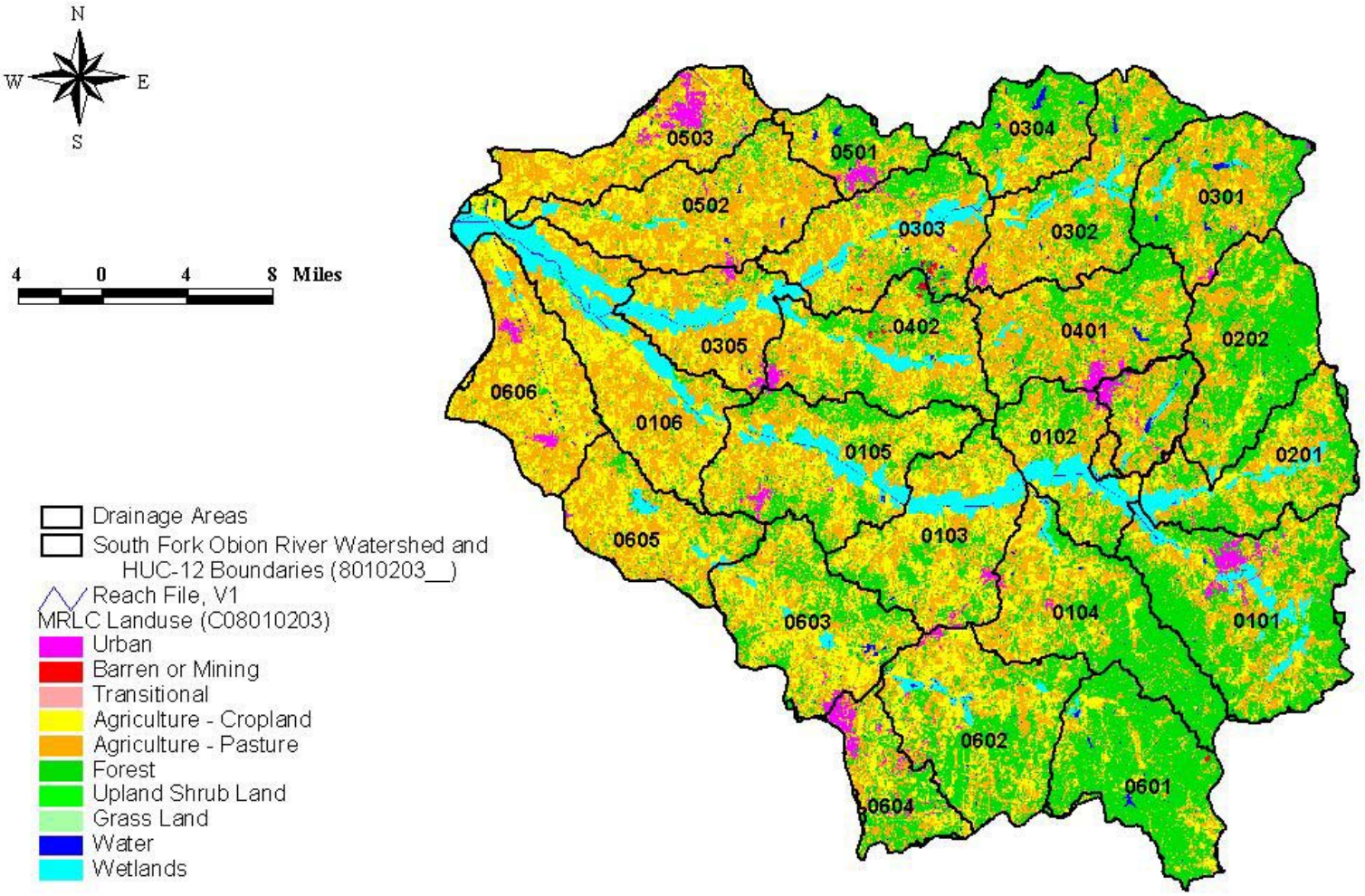

Figure 3. Land Use Characteristics of the South Fork Obion River Watershed.

Table 2. Final 2006 303(d) List for E. coli – South Fork Obion River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE / TMDL Priority	Pollutant Source
TN08010203001 – 0700	CLEAR CREEK	3.6	Loss of biological integrity due to Siltation Low dissolved oxygen Physical Substrate Habitat Alterations Escherichia coli	Channelization Upstream Impoundment Undetermined Source

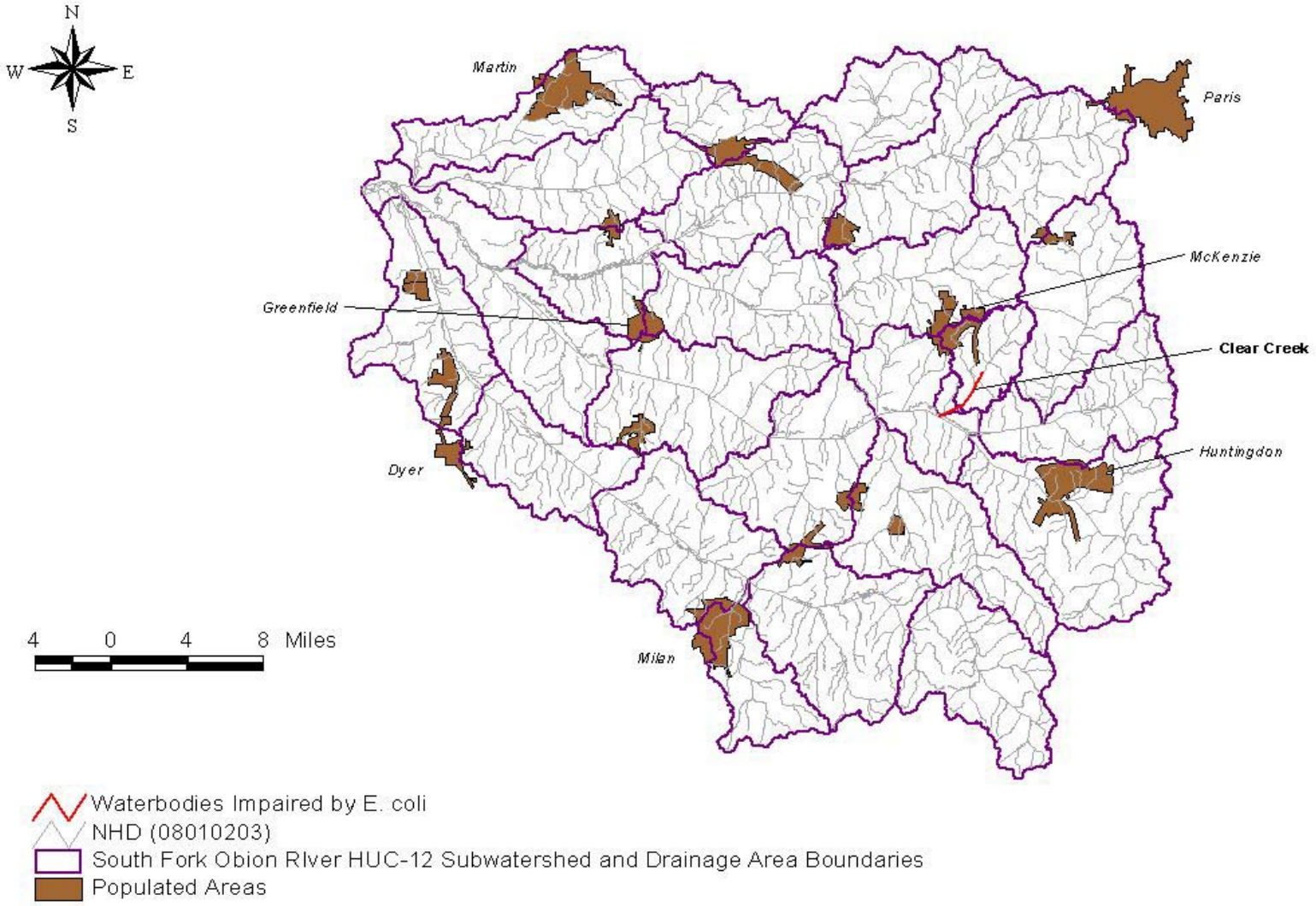

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2006 303(d) List).

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the South Fork Obion River waterbody includes fish & aquatic life, irrigation, livestock watering & wildlife, and recreation. Of the use classifications with numeric criteria for E. coli, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development. The coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January 2004* (TDEC, 2004a). Section 1200-4-3-.03 (4) (f) states:

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

As of February 2, 2006, the E. coli impaired waterbody in the South Fork Obion River watershed has not been designated as either a State Scenic River, Tier II, or Tier III stream.

The geometric mean standard for the E. coli group of 126 CFU/100 mL and the sample maximum of 941 CFU/100 mL have been selected as the appropriate numerical targets for TMDL development for the impaired waterbody.

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

There are three water quality monitoring stations that provide data for Clear Creek, identified as impaired for E. coli, in the South Fork Obion River watershed:

- HUC-12 080102030102:
    - CLEAR001.0CR – Clear Creek, upstream of Big Buck Road
    - CLEAR001.2CR – Clear Creek, at Big Buck Road
    - CLEAR003.5CR – Clear Creek, at Hwy 124/22

The locations of these monitoring stations are shown in Figure 5. Water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 941 CFU /100 mL maximum E. coli standard at two of the monitoring stations where E. coli samples were collected. Water quality monitoring results are summarized in Table 3.

Two of the water quality monitoring stations (Table 3 and Appendix B) have at least one E. coli sample value reported as >2419.2. In addition, at one of these sites, the maximum E. coli sample value is >2419.2. For the purpose of calculating summary data statistics, TMDLs, Waste Load

Allocations (WLAs), and Load Allocations (LAs), these data values are treated as (equal to) 2419.2. Therefore, the calculated results are considered to be estimates. Future E. coli sample analyses at these sites should follow established protocol. See Section 9.4.

There were not enough data to calculate the geometric mean at any of the monitoring stations. Whenever a minimum of 5 samples is collected at a given monitoring station over a period of not more than 30 consecutive days, the geometric mean is calculated.

Table 3. Summary of Water Quality Monitoring Data

Monitoring Station	E. Coli (Single Sample Max. WQ Target = 941 CFU/100 mL)					
	Data Pts.	Date Range	[CFU/100 mL]			Exceed WQ Max. Target
			Min.	Avg.	Max.	
CLEAR001.0CR	4	8/05-11/05	1	666.7	>2419.2	1
CLEAR 001.2CR	5	9/01-5/02	410.6	2402.5	7270	3
CLEAR 003.5CR	6	7/05-12/05	1	88.2	488.4	0

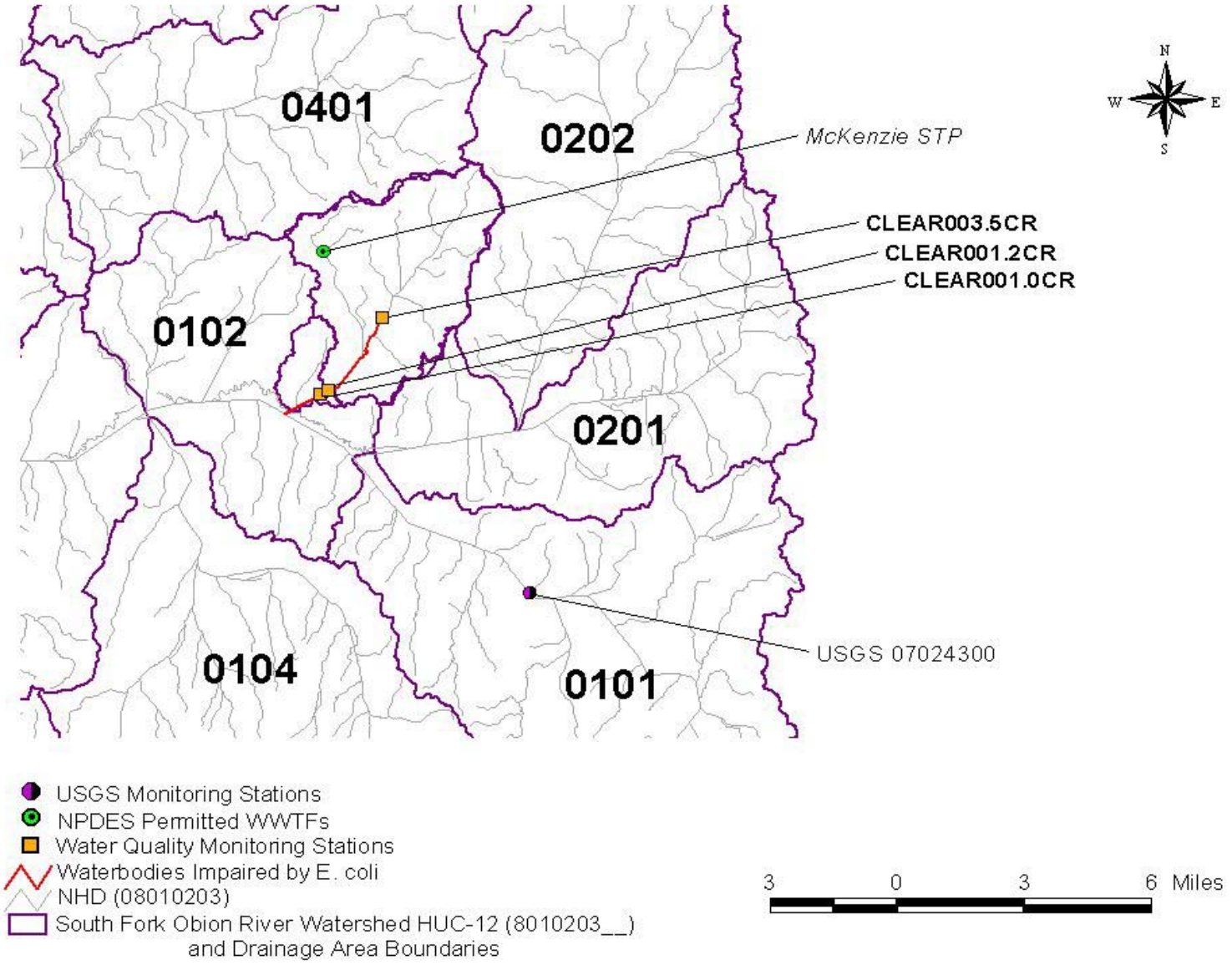

Figure 5. Monitoring Stations and NPDES permitted WWTFs in the South Fork Obion River Watershed.

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect E. coli loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL must provide WLAs for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a LA for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There was one (1) NPDES permitted WWTF in the Tennessee portion of the impaired subwatershed of the South Fork Obion River watershed authorized to discharge treated sanitary wastewater during the TMDL analysis period. This facility, the McKenzie Sewage Treatment Plant (STP), NPDES permit number TN0020613 (Figure 5) has a design capacity equal to 2.0 million gallons per day (MGD) and discharges to an unnamed tributary at mile 2.8 to Clear Creek at mile 2.4. The permit limits for discharges from this WWTF are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for protection of the recreation use classification.

Non-permitted point sources of (potential) E. coli contamination of surface waters associated with STP collection systems include leaking collection systems and sanitary sewer overflows (SSOs).

Note: As stated in Section 5.0, the current coliform criteria are expressed in terms of E. coli concentration, whereas previous criteria were expressed in terms of fecal coliform and E. coli concentration. Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform will be replaced by E. coli limits.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Phase I of the EPA storm water program requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. At present, there are no MS4s of this size in the South Fork Obion River watershed.

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program. A small MS4 is designated as *regulated* if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003). There are no permitted Phase II MS4s located in the drainage areas of (E. coli) 303(d)-listed waterbodies in the South Fork Obion River watershed.

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State road and interstate highway right-of-ways that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas.

Information regarding storm water permitting in Tennessee may be obtained from the Tennessee Department of Environment and Conservation (TDEC) website at:

http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of E. coli loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*, while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of August 14, 2006, there were five (5) Class II CAFOs in the South Fork Obion River watershed with coverage under the general NPDES permit. In addition, there were three (3) Class I CAFOs with individual permits located in the South Fork Obion River watershed. None of the CAFOs (Class I or Class II) are located in the drainage area of the (E. coli) 303(d)-listed waterbody.

7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The vast majority of waterbodies identified on the Final 2006 303(d) List as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.
- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).
- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2002 Census of Agriculture. Livestock data, for the county containing the E. coli-impaired subwatershed, are summarized in Table 4. Note that, due to confidentiality issues, any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

Table 4. Livestock Distribution in the South Fork Obion River Watershed

County Name	Livestock Population (2002 Census of Agriculture)*						
	Beef Cow	Milk Cow	Hogs	Sheep	Poultry (Layers)	Poultry (Broilers)	Horses
Carroll	9,300	232	1,777	40	458	(D)	1,193

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2002 Census of Agriculture that would disclose information about the operations of an individual farm or ranch. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

7.2.3 Failing Septic Systems

Some coliform loading in the South Fork Obion River watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. It is estimated, from 2000 county census data, that 27,514 people utilize septic systems in Carroll County, the county containing the E. coli-impaired subwatershed in the South Fork Obion River watershed, as compiled using the Watershed Characterization System (WCS). In western Tennessee, it is estimated that there are

approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. The percentage of urban land area for the impaired subwatershed (Clear Creek) in the South Fork Obion River watershed is approximately 6.0%. Land use for the South Fork Obion River impaired drainage area is summarized in Figures 6 and 7 and tabulated in Appendix A.

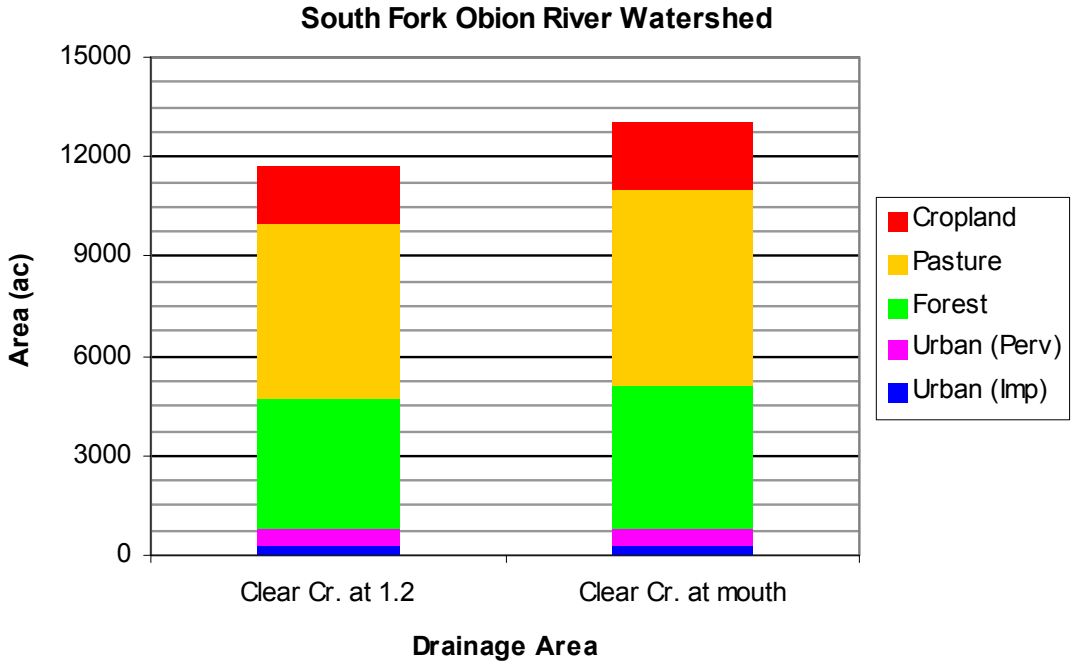

Figure 6. Land Use Area of South Fork Obion River Watershed Drainage Areas Clear Creek at the mouth and Clear Creek at mile 1.2.

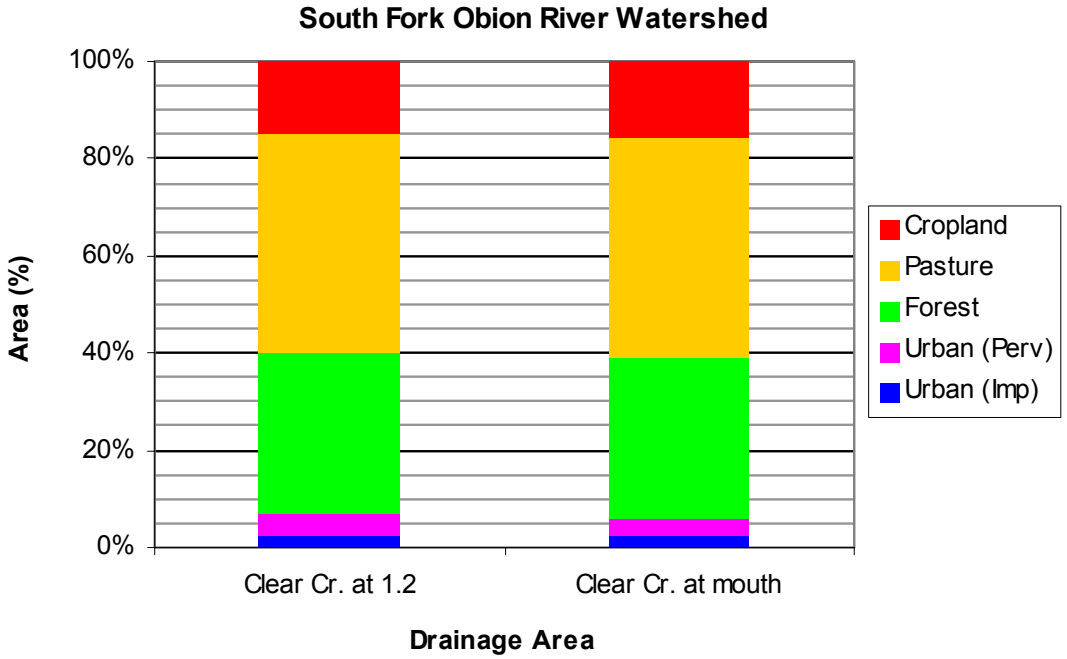

Figure 7. Land Use Percent of South Fork Obion River Watershed Drainage Areas Clear Creek at the mouth and Clear Creek at mile 1.2.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The Total Maximum Daily Load (TMDL) process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

This document describes TMDL, Waste Load Allocation (WLA), and Load Allocation (LA) development for the waterbody identified as impaired due to E. coli on the Final 2006 303(d) List.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, the E. coli TMDL is expressed as the percent reduction in in-stream loading required to decrease existing E. coli concentrations to desired target levels. WLAs & LAs for precipitation-induced loading sources are also expressed as required percent reductions in E. coli loading. Allocations for loading that is independent of precipitation (WLAs for WWTFs and LAs for "other direct sources") are expressed as CFU/day.

8.2 Area Basis for TMDL Analysis

The primary area unit of analysis for TMDL development is the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the Final 2006 303(d) List). In some cases, however, TMDLs are developed for an impaired waterbody drainage area only. Determination of the appropriate area to use for analysis was based on a careful consideration of a number of relevant factors, including: 1) location of the impaired waterbody in the HUC-12 subwatershed; 2) land use type and distribution; 3) water quality monitoring data; and 4) the assessment status of other waterbodies in the HUC-12 subwatershed. The TMDL for the South Fork Obion River watershed was developed on an impaired waterbody drainage area basis.

8.3 TMDL Analysis Methodology

The TMDL for the South Fork Obion River watershed was developed using load duration curves for analysis of the impaired waterbody drainage area. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow regime represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in the impaired waterbody and an overall load reduction calculated to meet E. coli targets according to the methods described in Appendix C.

8.4 Critical Conditions and Seasonal Variation

The critical condition for non-point source E. coli loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, E. coli bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low streamflow when dilution is minimized. Both conditions are represented in the TMDL analyses.

The ten-year period from January 1, 1996 to December 31, 2005 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbody. In most cases, water quality data have been collected during most flow ranges. Based on the location of the water quality exceedances on the load duration curve, high flow appears to be the dominant delivery mode for E. coli (see Section 9.3 and Appendix C).

Seasonal variation was incorporated in the load duration curves by using the entire 10-year simulation period and all water quality data collected at the monitoring stations. Water quality data were collected during all seasons.

8.5 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For development of the E. coli TMDL in the South Fork Obion River watershed, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum (lake, reservoir, State Scenic River, Tier II, Tier III):	MOS = 49 CFU/100 ml
Instantaneous Maximum (other):	MOS = 94 CFU/100 ml
30-Day Geometric Mean:	MOS = 13 CFU/100 ml

8.6 Determination of TMDLs

An E. coli load reduction was calculated for the impaired segment in the South Fork Obion River watershed using LDCs to evaluate compliance with the single sample maximum target concentrations according to the procedure in Appendix C. If sufficient data were available, a load reduction would be developed to achieve compliance with the 30-day geometric mean target concentration. Both in-stream load reductions would be compared and the largest calculated load reduction would be selected as the TMDL. The TMDL load reduction for the impaired segment is shown in Table 5. In cases where the geometric mean can not be developed, it is assumed that achieving the load reduction based on the single sample maximum target concentration should result in attainment of the geometric mean criteria.

8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the higher load reductions necessary to achieve in-stream targets after application of the explicit MOS. WLAs for existing WWTFs are equal to their existing NPDES permit limits. Since WWTF permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge and recognition that loading from these facilities is generally small in comparison to other loading sources, further reductions were not considered to be warranted. WLAs for CAFOs and LAs for "other direct sources" (non-precipitation induced) are equal to zero. WLAs & LAs are summarized in Table 5.

Table 5. WLAs & LAs for South Fork Obion River, Tennessee

HUC-12 Subwatershed (08010203__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs[a,b]			LAs[e]
				WWTFs[c]		Leaking Collection Systems[d]	
				Monthly Avg.	Daily Max.		
			[% Red.]	[CFU/day]	[CFU /day]	[CFU /day]	[% Red.]
0102	Clear Creek	TN08010203001 – 0700	82.3	9.541×10^{9}	7.125×10^{10}	0	84.1

a. *There are no CAFOs in the impaired subwatershed of the South Fork Obion River watershed. All future CAFOs will be assigned waste load allocations (WLAs) of zero.*

b. *There are no MS4s in the impaired subwatershed of the South Fork Obion River watershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.*

c. *WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet in-stream water quality standards at the point of discharge as specified in their NPDES permits.*

d. *The objective for leaking collection systems is a WLA of zero. It is recognized, however, that a WLA of 0 CFU/day may not be practical. For these sources, the WLA is interpreted to mean a reduction in E. coli loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.*

d. *The load allocations (LAs) listed apply to precipitation induced nonpoint sources only. The objective for all other nonpoint sources (leaking septic systems, illicit discharges, and animals access to streams) is a LA of zero. It is recognized, however, that for leaking septic systems a LA of 0 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in E. coli loading to the maximum extent feasible, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.*

9.0 IMPLEMENTATION PLAN

The TMDL, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waterbodies in the South Fork Obion River watershed through reduction of excessive E. coli loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

9.1 Point Sources

9.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times, including elimination of bypasses and overflows. In Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTFs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day.

9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For future regulated discharges from municipal separate storm sewer systems, WLAs are and will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Plan (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include the following six minimum control measures:

- Public education and outreach on storm water impacts
- Public involvement/participation
- Illicit discharge detection and elimination
- Construction site storm water runoff control
- Post-construction storm water management in new development and re-development
- Pollution prevention/good housekeeping for municipal operations

The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:

- Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.

- Analytical monitoring of pollutants of concern in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time.

- In-stream biological monitoring at appropriate locations to demonstrate recovery of biological communities after implementation of storm water control measures.

When applicable, the appropriate Division of Water Pollution Control Environmental Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4. Details of monitoring plans and monitoring data should be included in annual reports required by MS4 permits.

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to CAFOs will be implemented through NPDES Permit No. TNA000000, General NPDES Permit for *Class II Concentrated Animal Feeding Operation* or the facility's individual permit. Among the provisions of the general permit are:

- Development and implementation of a site-specific Nutrient Management Plan (NMP) that:

    - Includes best management practices (BMPs) and procedures necessary to implement applicable limitations and standards;
    - Ensures adequate storage of manure, litter, and process wastewater including provisions to ensure proper operation and maintenance of the storage facilities.
    - Ensures proper management of mortalities (dead animals);
    - Ensures diversion of clean water, where appropriate, from production areas;
    - Identifies protocols for manure, litter, wastewater and soil testing;
    - Establishes protocols for land application of manure, litter, and wastewater;
    - Identifies required records and record maintenance procedures.

    The NMP must be submitted to the State for approval and a copy kept on-site.

- Requirements regarding manure, litter, and wastewater land application BMPs.

- Requirements for the design, construction, operation, and maintenance of CAFO liquid waste management systems that are constructed, modified, repaired, or placed into operation after April 13, 2006. Final design plans and specifications for these systems must meet or exceed standards in the NRCS Field Office Technical Guide and other guidelines as accepted by the Departments of Environment and Conservation, or Agriculture.

Provisions of individual CAFO permits are similar. NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* is available on the TDEC website at http://state.tn.us/environment/wpc/ppo/CAFO%20Final%20PDF%20Modified.pdf.

9.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation has no direct regulatory authority over most nonpoint source (NPS) discharges. Reductions of E. coli loading from nonpoint sources will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. Local citizen-led and implemented management measures have the potential to provide the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and non-governmental levels to be successful.

BMPs have been utilized in the South Fork Obion River watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., pasture and hayland planting, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in the South Fork Obion River E. coli-impaired subwatershed during the TMDL evaluation period. The Tennessee Department of Agriculture (TDA) keeps a database of BMPs implemented in Tennessee. Those listed in the South Fork Obion River watershed are shown in Figure 8. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future TMDL analysis efforts.

It is further recommended that additional BMPs be implemented and monitored to document performance in reducing coliform bacteria loading to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established and maintained and their performance (in source reduction) evaluated over a period of at least two years prior to recommendations for utilization for subsequent implementation. E. coli sampling and monitoring are recommended during low-flow (baseflow) and storm periods at sites with and without BMPs and/or before and after implementation of BMPs.

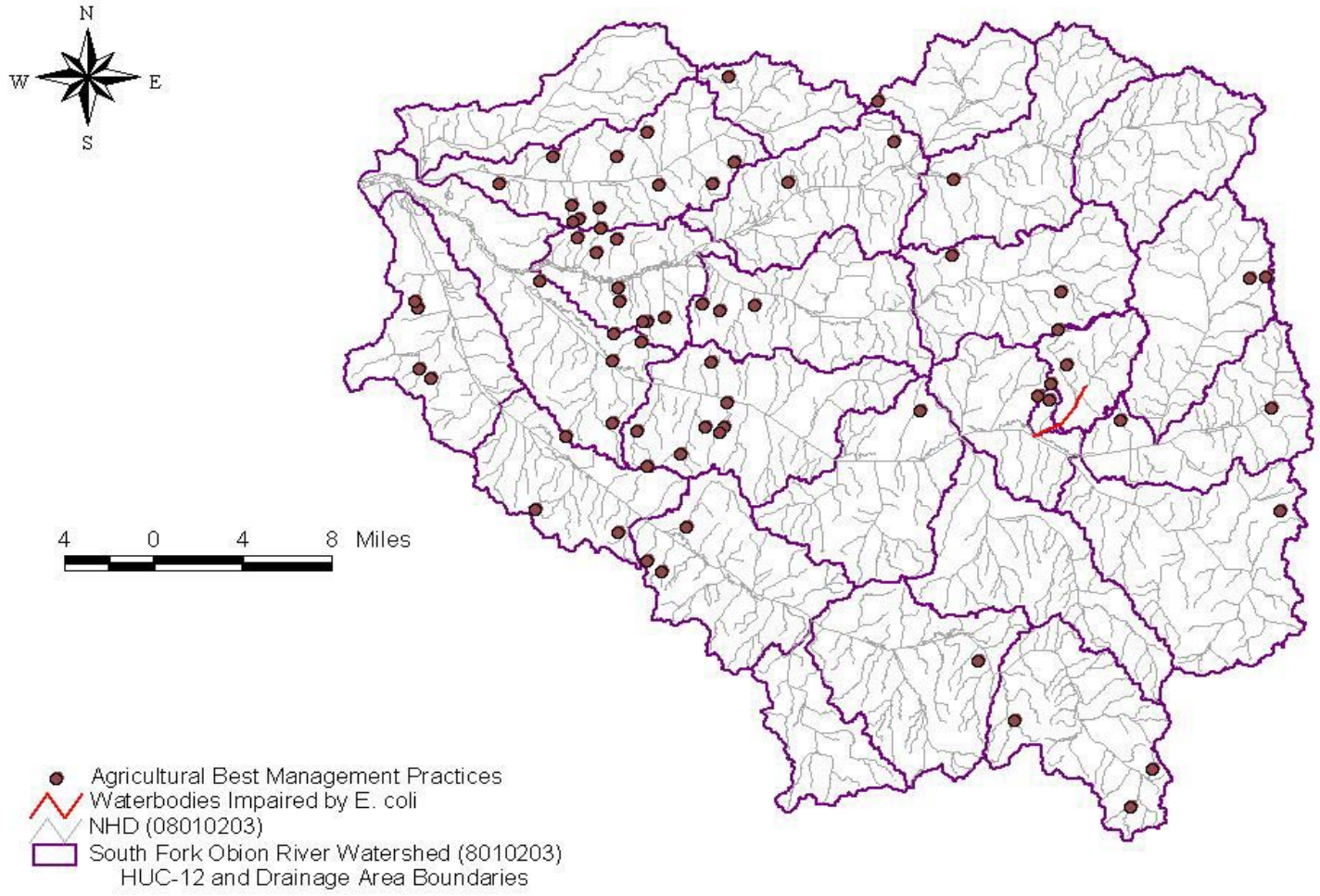

Figure 8. Tennessee Department of Agriculture Best Management Practices in the South Fork Obion River Watershed.

9.3 Example Application of Load Duration Curves for Implementation Planning

The Load Duration Curve methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting strategies to appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of E. coli by differentiating between point and non-point problems. The load duration curve analysis can be utilized for implementation planning. The E. coli load duration curve for Clear Creek at Mile 1.2 (Figure 9) was analyzed to determine the frequency with which water quality monitoring data exceed the E. coli target maximum concentration of 941 CFU/100 mL under five flow conditions (low, dry, mid-range, moist, and high). Observation of the plot suggests the Clear Creek subwatershed is impacted by point and possibly non-point-type sources.

Table 6 presents Load Duration Curve analysis statistics for E. coli and example implementation strategies for each source category covering the entire range of flow (Stiles, 2003). Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. Results indicate the implementation strategy for the Clear Creek subwatershed will require BMPs targeting point sources (dominant under low flow/baseflow conditions) and non-point sources (dominant under high flow/runoff conditions). The implementation strategies listed in Table 6 are a subset of the categories of BMPs and implementation strategies available for application to the South Fork Obion River subwatershed for reduction of E. coli loading and mitigation of water quality impairment.

See Appendix C for a detailed discussion of the Load Duration Curve Methodology applied to the South Fork Obion River watershed.

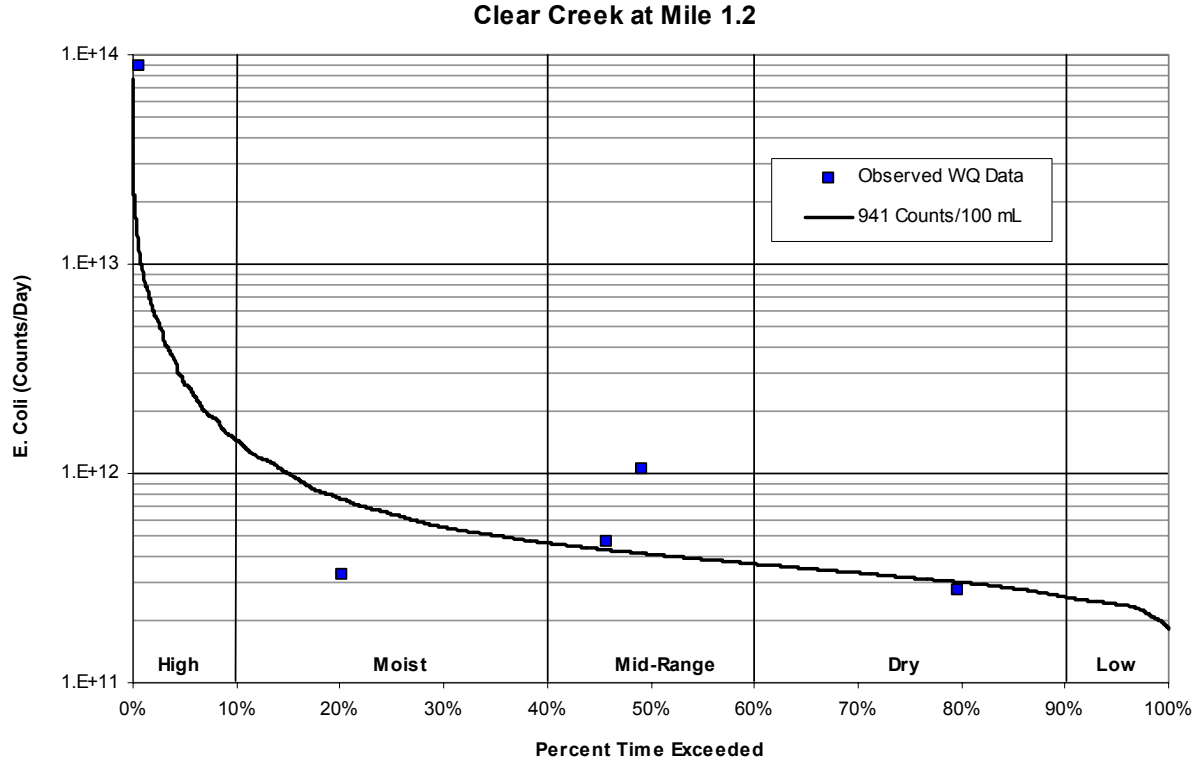

Figure 9. Load Duration Curve for Implementation Planning.

Table 6. Example Implementation Strategies

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Municipal NPDES		L	M	H	H
Stormwater Management		H	H	H	
SSO Mitigation	H	H	M	L	
Collection System Repair		L	M	H	H
Septic System Repair		L	M	H	M
Livestock Exclusion[1]			M	H	H
Pasture Management/Land Application of Manure[1]	H	H	M	L	
Riparian Buffers[1]		H	H	H	
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

[1] Example Best Management Practices for Agricultural Source reduction. Actual BMPs applied may vary.

9.4 Additional Monitoring

Documenting progress in reducing the quantity of E. coli entering the South Fork Obion River watershed is an essential element of the TMDL Implementation Plan. Additional monitoring and assessment activities are recommended to determine whether implementation of TMDLs, WLAs, & LAs in tributaries and upstream reaches will result in achievement of in-stream water quality targets for E. coli. Future monitoring activities should also be adequate to assess water quality using the 30-day geometric mean standard.

Tennessee's watershed management approach specifies a five-year cycle for planning and assessment. Each watershed will be examined (or re-examined) on a rotating basis. Generally, in years two and three of the five-year cycle, water quality data are collected in support of water quality assessment (including TMDL development) and planning activities. Therefore, a watershed TMDL is developed one to two years prior to commencement of the next cycle's monitoring period. Monitoring to document improvements and/or identify the need for additional remediation efforts is expected to continue during subsequent watershed cycles.

Additional monitoring and assessment activities are recommended for the South Fork Obion River watershed E. coli-impaired subwatershed to verify the assessment status of the stream reaches identified on the Final 2006 303(d) List as impaired due to E. coli. If it is determined that these stream reaches are still not fully supporting designated uses, then sufficient data to enable development of a TMDL must be acquired. Future monitoring activities should be representative of all seasons and a full range of flow and meteorological conditions. In addition, collection of E. coli data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2004a), is encouraged. Finally, for individual monitoring locations, where historical E. coli data are greater than 1000 colonies/100 mL (or future samples are anticipated to be), a 1:100 dilution should be performed as described in Protocol A of the *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2004b).

9.5 Source Identification

An important aspect of E. coli load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of E. coli impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and E. coli affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in E. coli impaired waterbodies.

Bacterial Source Tracking is a collective term used for various biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (Shah, 2004). In general, these methods rely on genotypic (also known as "genetic fingerprinting"), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR). Phenotypic techniques generally involve an antibiotic resistance analysis (Hyer, 2004).

The USEPA has published a fact sheet that discusses BST methods and presents examples of BST application to TMDL development and implementation (USEPA, 2002b). Various BST projects and descriptions of the application of BST techniques used to guide implementation of effective BMPs to remove or reduce fecal contamination are presented. The fact sheet can be found on the following EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

A multi-disciplinary group of researchers at the University of Tennessee, Knoxville (UTK) is developing and testing a series of different microbial assay methods based on real-time PCR to detect fecal bacterial concentrations and host sources in water samples (McKay, 2005). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources. Additional information can be found on the following UTK website: http://web.utk.edu/~hydro/Research/McKayAGU2004Abstract.pdf.

9.6 Evaluation of TMDL Implementation Effectiveness

The effectiveness of the TMDL implementation will be assessed within the context of the State's rotating watershed management approach. Watershed monitoring and assessment activities will provide information by which the effectiveness of E. coli loading reduction measures can be evaluated. Additional monitoring data, ground-truthing activities, and bacterial source identification actions are recommended to enable implementation of particular types of BMPs to be directed to specific areas in impaired subwatersheds. This will optimize utilization of resources to achieve maximum reductions in E. coli loading. These TMDLs will be re-evaluated during subsequent watershed cycles and revised as required to assure compliance with applicable water quality standards.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed E. coli TMDL for the South Fork Obion River watershed will be placed on Public Notice for a 35-day period and comments solicited. Steps that will be taken in this regard include:

1) Notice of the proposed TMDL will be posted on the TDEC website. The announcement will invite public and stakeholder comment and provide a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDL (similar to the website announcement) will be included in one of the NPDES permit Public Notice mailings which will be sent to approximately 90 interested persons or groups who have requested this information.

3) A draft copy of the proposed TMDL will be sent to the Tennessee Department of Transportation.

4) A letter will be sent to the McKenzie Sewage Treatment Plant (TN0020613), located in the E. coli-impaired subwatershed in the South Fork Obion River watershed and permitted to discharge treated effluent containing E. coli, advising them of the proposed TMDL and its availability on the TDEC website. The letter will also state that a copy of the draft TMDL document will be provided on request.

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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